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(54) Title: TRANSFORMER WITH MAGNETIC CORE OF COILED WIRES

(57) Abstract

Such invention relates to a transformer, the core of which is not constructed with magnetic laminations. The current transformers have a magnetic core (1) formed by laminations cut in the width and length and this stacked until the thickness intended is obtained. The lamination width times the stack thickness determine the cross-section of the core (1). Around the legs (5) of this core are installed primary (6) and secondary (8) coils. The transformer, object of such patent, has a magnetic core made of magnetic wires (17) wound around the coils (13), which are made of copper or aluminum conductors. The coils (13) can be wound in circular, oval, square shapes and so on and around these coils, the magnetic core is constructed not stacking laminations any longer, but winding magnetic steel wires or other alloys magnetic wires by means of appropriate winding machines, such as the toroidal winding machines. In the transformer (in figure 3 or 4) the core section (19) is given by the cross-section area of each wire (17) multiplied by the number of turns winded around the winding (13), formed with one, two or more insulated coils which are made of electrical conductors also insulated with respect to each other.

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TRANSFORMER WITH MAGNETIC CORE OF COILED WIRES

The present invention relates to a new type of transformer, the constructive form of which is based on a new concept of magnetic core.

Since its invention by the end of the last century, the transformer faced no important change, being basically constituted of a magnetic core formed by silicon rolled steel sheet, with surface insulation and stacked up to the project thickness and, around the magnetic core there are wound copper or aluminum conductors, also insulated, forming coils in which the coil receiveing the power supply voltage and generating the flux in the magnetic core is called primary coil, and the coil in which the induced voltage appears, is called secondary coil.

The progress registered in the manufacture of transformers for the last 100 years has been exclusively due to the evolution of the magnetic steel until reaching the modern oriented grain and laser- irradiate silicon steel sheet.

The evolution in the quality of the magnetic laminations has made it possible to build high-magnetic permeability cores and low losses, making it possible to build small-sized transformers nowadays, with rather low magnetizing currents and losses, compared to earlier transformers.

Nevertheless, in spite of the excellent quality of the magnetic lamination and the technical improvement in the assembling, the transformer built nowadays remains constructively identical to the one constructed a century ago. Moreover, at least at

medium term there are no perspectives of new technological advances relating to the laminated magnetic silicon steel of the core.

Aiming at contributing to the technical progress of the transformers, we are proposing, in this patent, a new type of transformer, its the magnetic core consisting of magnetic wires and no more of magnetic laminated steel.

Preliminary studies and calculations have shown that the transformer presented herein can represent a qualitative advance in the manufacture of transformers, especially in relation to the medium-sized ones, resulting in the weight reduction of the active parts, such as the core and windings and with large reductions of core losses, in the magnetizing current and in load losses.

For a better understanding and knowledge of the new idea to be described as follows, the attached Figures describe it not in a restrictive way but rather by way of an example, where :

Figure 1 shows a perspective and partially sectional view of the basic assembly of a transformer as manufactured nowadays, with a silicon magnetic steel laminated core and concentric primary and secondary windings wound around the core.

Figure 2 shows a perspective view of the manufacture of a transformer with a toroidal core made with a continuous grain oriented electrical magnetic laminated strip, with the respective primary and secondary windings around the core as schematically outlined.

Figure 3 shows the new type of transformer, where the primary and secondary coils are circular shaped and the magnetic-wire core is coiled around the conductor coils.

Figure 4 shows one of the possible variants of the new transformer with the same constructive features of Figure 3, that is, with its core coiled around the electrical conductor coils.

The transformer of Figure 1 represents the type of basic construction which is being used until today with few or no alterations at all. The Figure shows, in a simplified way, a single-phase transformer with a magnetic core (1) of two legs (5) and two coils (2).

The transformer consists of a core (1) composed of high-magnetic permeability silicon laminations (3) which are cut, and overlapped with respect to each other (3), constituting the laminated magnetic core (1). The core transversal area is given by the laminations width times the thickness of the same stacked laminations.

The laminations are coated with an insulating layer of a high-resistivity millfinish, assuring the insulation of one lamination from the other, in order to reduce the eddy-current losses of the core (1) . In the modern cold-laminated silicon steel sheets, the grain of the magnetic material are oriented to the lamination direction during the process, increasing the magnetic permeability in the rolled direction.

In the construction of the magnetic core, the strip of grain oriented laminations is often cut in the joints (4) with 45° inclination, so that the magnetic permeability is maintained in a high level also at those points where magnetic flux changes its direction.

Around the vertical legs (5) of the core (1) coils (2) are placed, normally composed of copper or aluminum insulated conductors, constituting the primary (6), which is separated by means of an insulation (7) from the other winding, constituting the secondary

(8). The function of the primary or secondary may be inverted without any change in the transformer operation. Usually we call induction coil or primary that receives in its terminals the power supply voltage; and secondary that winding where appears the voltage induced by the magnetic flux that circulates inside the core and that is generated by the magnetizing current of the primary winding.

The construction of transformers can show technical variations, not just related in converting one voltage to another voltage. For example, among them, we find the magnetic core reactors or inductors, insulation transformers, transformers for impedance matches, measuring transformers, phase shift transformers, etc.

The transformer of Figure 2 shows a construction with toroidal core (10). The toroidal core is a wound magnetic core made by a continuous strip (9) of oriented grain silicon steel, coiled in the rolled direction up to the preset thickness. The strip width defines the height of the core (10).

In the toroidal core are wound two coils (11) and (12), as schematically outlined to simplify the drawing. When an alternate voltage is applied to one of the coils, for instance to the coil (12), magnetizing current starts to flow in this coil (12). This will cause to flow in the core an alternate magnetic flux, which produces, by induction, a voltage in the coil (11) according to the turns ratio between both coils.

The toroidal core made of oriented grain silicon steel strip is currently the most efficient existing magnetic core.

This is mainly due to the fact that the core is not cut and consequently does not shows the joints (4), as those seen in the core of Figure 1. The joints (4) in a magnetic core represent air gaps,

that is, air gaps between the lamination, which reduce the total permeability of the core . In the toroidal core (10) there are no air-gaps.

Although this core provides the best magnetic features, it is used only for small transformers, due to the difficulties in the assembling of large units. The construction of the core of Figure 1 made of cut and stacked silicon steel laminations is the construction used worldwide, varying from a few watts up to hundreds of megawatts of power.

The conductors of coils (11) and (12) of the toroidal core of Figure 2 are coiled by means of appropriate toroidal coiling machines winding up to thousands of turns per minute .

The transformer of Figure 3, which shows the newness of this present patent request, uses a completely different shape from the conventional transformers shown in Figures 1 and 2.

Contrary to the conventional cores manufactured with magnetic silicon steel laminations, the new type of magnetic core uses steel wires or other magnetic alloy wires.

The basic idea of the new transformer consists in the construction of a circular winding (13), making up of two coils (14) and (15), as shown in sectional view (Figure 3). The two coils (14) and (15), one on the other, and formed by conductors, insulated with respect to each other, are separated by an insulating material (16) that can also be an air gap. Other geometric shapes are also possible with the two coils (14) and (15), which can be one, two or more coils, one winded beside the other, one on the other or alternated. The winding (13) must not necessarily be circular, it being possible, for example to be made in a square, rectangular, oval or elliptical shape.

On the winding (13) one or more magnetic steel wires in parallel (17) are coiled. The magnetic wire is coiled in such many layers, from one end to the other of the winding (13), until reaching the thickness (18) to obtain the required cross section of the core (19).

The magnetic steel wires or other magnetic alloys wires shall be normally coiled around the winding (13) by toroidal coiling machines.

In Figure 3, the core (19) shown may give a better idea of the final result.

The core (19) literally covers with a compact and continuous magnetic tick layer and with the required thickness the winding (13) of electrical conductors, which are the coils (14) and (15), respectively primary and secondary of a transformer.

The total section of the magnetic core shall be the thickness of the core times the length of the circular core or rather, the cross section of the magnetic wire (17) times the number of total turns of coiled wires. The winded core (19) may be extended to all the winding (13) circumference, leaving, as necessary, an uncovered segment free for the outlet of the feed wires (20) of both primary and secondary coils. According to the above explanation, a complete constructive inversion in the transformer as it is known in the state of the art can be seen. Instead of the coils being winded around the core, it is the core which is winded around the coils.

Just like the magnetic steel lamination in Figure 1, the magnetic steel wire shall also be coated with an insulating film so as to provide insulation between the coiled magnetic steel wires wound on the windings (14) and (15) .

Figure 4 shows an oval winding (23), provided with two relatively long straight core segments (21). The magnetic steel wire core is winded only at the straight segments (21) making easier its construction. One or both of the curved segments (22) without winded core can be used to primary and secondary coils connections.

The new type of transformer, made of wound magnetic steel wires, has several advantages over the conventional transformers with a laminated core.

A single-phase 100 KVA transformer, calculated with the same magnetic induction in the core and the same current density in the conductor windings, showed that the transformer designed as per Figure 3 had 10 % less copper by weight and 24% less core by weight relative to the laminated transformer of Figure 1.

One of the main advantages of the core with coiled wires in relation to the laminated core is the geometry.

Through the transformer of Figure 3 it can be seen that the transversal area of the core is the transversal area of each wire times the number of coiled turns. With such arrangement the mean path length of magnetic flux is well reduced, beeing correspondent with the mean circumference of the core, formed by the wires.

For comparison purposes only, the mean path length in the case of the 100 KVA core, made with wound wires, was 48 cm, knowing that in the 100 KVA core made with laminations it was 125 cm. In the wired core the magnetizing current, for example, will be smaller than in the traditional laminated core.

Some other advantages can also be mentioned:

The core coiled with magnetic wires does not have air gaps due to joints (4), existing between the laminations core of Figure 1.

Producing the magnetic wires with reduced diameters, the core losses can be practically reduced to insignificant amounts, what is extremely desirable, as in the case of distribution transformers. Considering the hundredths of thousands of distribution transformers spread all over the country, one could imagine the power saving resulting from low core losses, which together with the power saving from the transformer windings, due to the less weight necessary for transformer windings, can represent a substantial saving of electrical power.

We have another very important advantage of the magnetic wired core regarding the laminated core: the grain oriented eledctrical steel sheet can only be produced in huge mills, which demand investments of billions of dollars, the production being therefore restricted to great-sized manufacturers only.

Considering that the wire drawing process is simpler, easier and more versatile than the lamination operation, and considering that a small wire drawing plant will can cost hundredths of times less than a steel industry required to produce magnetic silicon steel sheet, this will enable a large number of small-sized producers to be able to produce the magnetic wire of steel or other alloys to use in the transformers with core of magnetic wire. Certainly this will reduce the transformer cost, especially those of distribution type and will surely enable a technological advance regarding the quality of the magnetic wires by means of the plurality of alternatives that many small and medium-sized manufacturers may offer.

The new transformer intends to be a complementary to the laminated core transformers, aiming valid alternative for multiple uses, especially in little and medium-size transformers.

Quite sure it can also be stated that the magnetic wire for coiled core shall enable, after a stage of adaptation and development, the use of magnetic inductions much higher than 1.7 Tesla used nowadays in the laminated core transformers. Therefore, increasing the induction in the core formed by coiled magnetic wires, we will have an ulterior reduction in weight and in dimensions of transformers and so in losses.

Due to the small investments necessaries to the wire drawing process when compared with the lamination process, the return and development of magnetic wires will be larger and faster.

Another essential element regarding the conventional laminated core is that the core wired transformer assembly can be completely automated because there is no need for manual assembling, which until today has not been solved, and which is necessary to stack the magnetic laminations cut into tailor-made pieces for each transformer.

In the transformer with core made of magnetic steel wire or its alloys, whatever its type or size of the transformer, the magnetic wire winding around the primary and secondary coils shall always be made by toroidal winding machines.

One of the much favorable possibility to the use of steel wire is the large number of wire diameters that can be used in the construction of transformers, from very thin wires which will enable the construction of core with nearly no losses and with very high

magnetic field intensity, as well as cheaper and simpler transformers using wires of larger diameters.

Besides, the core construction features with magnetic coiled wire assure between the primary (14) and secondary (15) coils a coupling factor near 1 (one) , that is, leakage inductance extremely low, which under many aspects is a substantial advantage.

CLAIMS

1 - TRANSFORMER WITH MAGNETIC CORE OF COILED WIRES, characterized by a winding (13) formed by one or more primary (14) and secondary (15) coils which may be circular-shaped or not, there existing the possibility of the coils be wound one on the other, or one besides to the other, alternated, more or less spaced or with other transversal forms, on the same it being wound by means of appropriate machines a magnetic core (19), formed by one or more parallel wires (17) wound around the winding (13), these wires being manufactured with magnetic steel and its alloys or with other also magnetic alloys, in a way that the wires are insulated by a thin film (17) formed by oxides, resins, varnishes or other insulating substances and wound across the winding (13) until the thickness necessary to meet the project data, then forming a magnetic wired compact core (19), the cross-section of which is the cross-section of each wire times the number of total turns distributed along the profile formed by the winding (13), in a way that in this core shall circulate a magnetic flux generated by the primary coil (14), and this magnetic flux will produce by induction a voltage that appears in the secondary coil (15).

2. TRANSFORMER WITH MAGNETIC CORE OF COILED WIRES according to Claim I, characterized by oval-shaped (23) coils (Figure 4) with straight segments (21) and curve segments (22), it being possible for the coil shape to have other geometrical figures as, for example, square, rectangular, oval or elliptical, knowing that the magnetic wire (17) is wound only in the straight segments (21), which make easier the construction of the core (19) at the same

time that one or two curve segments of the winding can be reserved for the connections (20) of the primary and secondary coils.

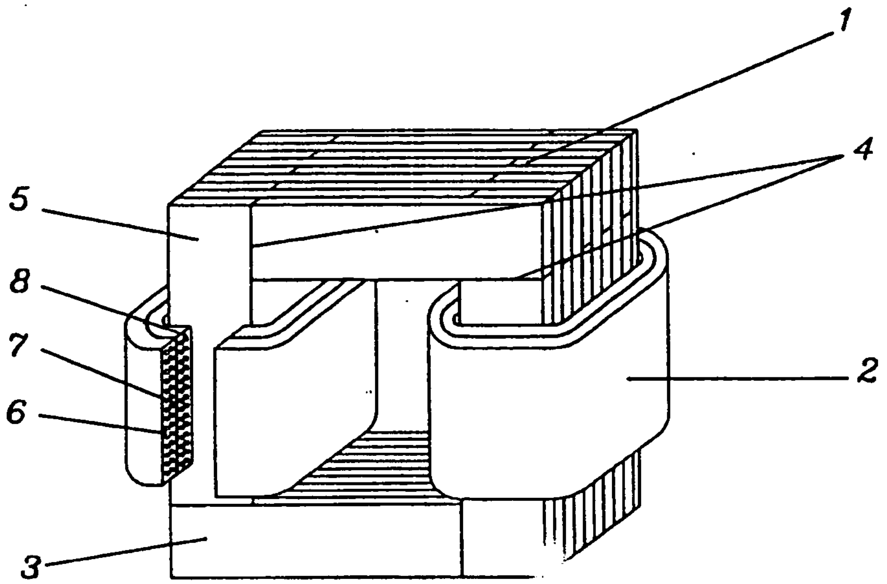

FIGURA 1

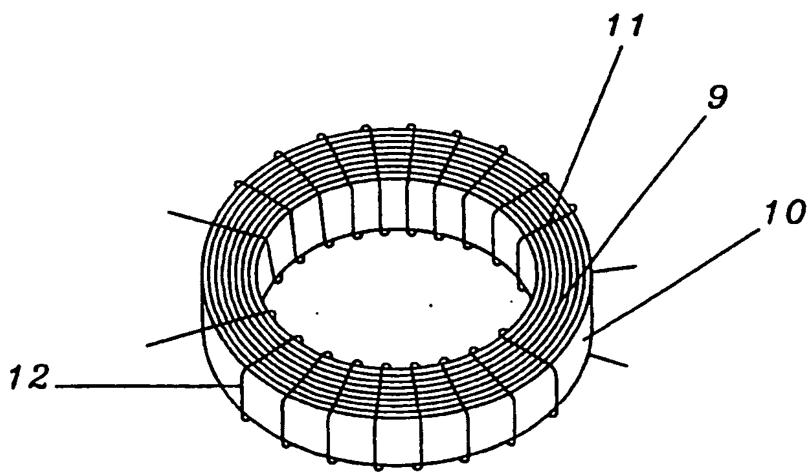

FIGURA 2

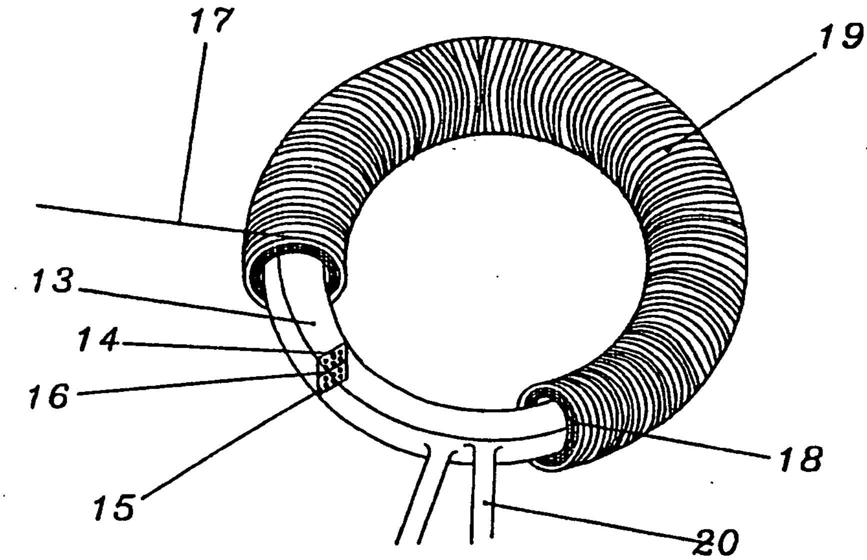

FIGURA 3

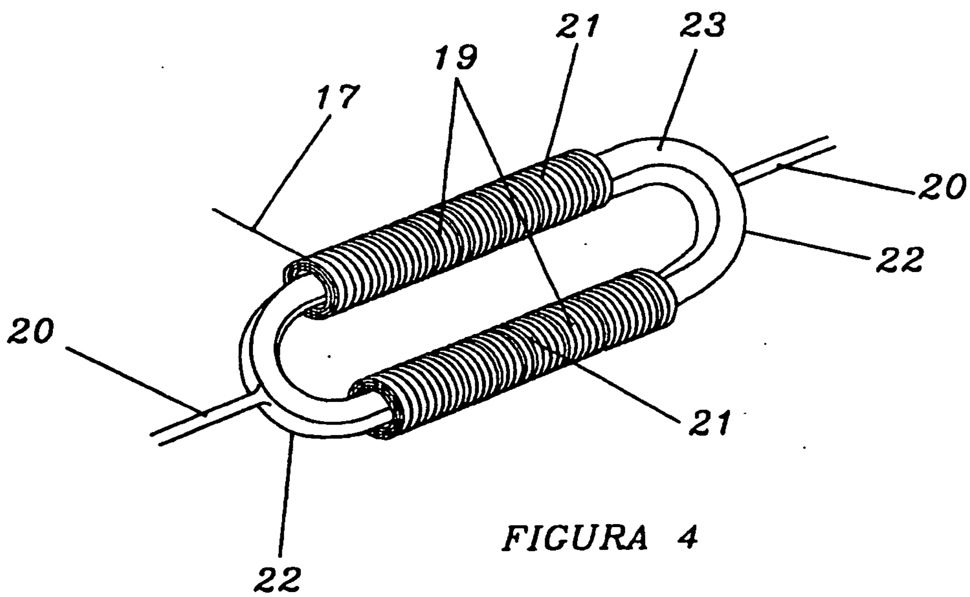

FIGURA 4